
Article:
Hughes, Vincent orcid.org/0000-0002-4660-979X and Wormald, Jessica Hazel (2020) Sharing innovative methods, data and knowledge across sociophonetics and forensic speech science. Linguistics Vanguard. ISSN 2199-174X

https://doi.org/10.1515/lingvan-2018-0062

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1 Introduction

Sociophonetics and forensic speech science (see French and Stevens 2013) are two disparate fields which, on the face of it, have very different aims. Yet, in many ways, sociophonetics and forensic speech science are two ends of the same continuum. Sociophonetics considers phonetic variation in order to explore how individuals and groups use language to enact identities, while forensic speech science strives to understand how individuals differ from each other. Taken from this perspective, it is easy to see the potential cross-over between the fields. Indeed, the forensic analysis of the voice has been, and largely still is, an application of methods and knowledge from sociophonetics.

Nevertheless, in recent years there has been growing divergence between the fields. One reason for this is their respective successes as independent research areas. As discussed by Foulkes, Scobbie and Watt (2010), sociophonetics is a relatively new field of linguistics, but one which has grown exponentially over its short history. As shown by this special issue, sociophonetics is now responsible for considerable methodological innovation; this in turn offers new insights into the nature of language variation and change, as well as providing evidence to test fundamental questions of phonetic and phonological theory. Research is now also increasingly focused on exploring the social meaning of linguistic variables in interactions. The use of multiple linguistic features by speakers is assessed across speaking styles and varying stances, with research demonstrating the diverse and flexible uses of specific linguistic variants which allows individuals to express their identities in different ways in different contexts (see e.g. Eckert 2012). This involves assessing multiple instances of speech from the same individuals and a move away from macro-social categories.

Over the last three decades, a growing body of subject-specific research has also spurred on developments in forensic analysis and evaluation techniques, with forensic speech science becoming an independent discipline, spanning primarily linguistics and speech technology, but also statistics, engineering, psychology, and law. However, the face of forensic science is changing, with increasing demands for the use of more scientific, data-driven methods, as opposed to evidence that relies on the analyst's experience (see more below). Forensic labs from all disciplines are now under pressure to become accredited in line with international standards and to validate methods to show empirically that they work; i.e. does the

application of sociophonetic methodologies adequately enable the expert to offer a view on whether two voices are from the same or different speakers?

Given this backdrop, it is our view that closer collaboration and exchange of knowledge and methods between sociophonetics and forensics is now more vital than ever as both fields explore within-speaker variability across different contexts, but with different ultimate goals. In this paper, we review the relationship between sociophonetics and forensic speech science, whilst also considering opportunities for closer collaboration between the fields. We have three specific aims:

1. To review current forensic casework practices to provide context for those readers unfamiliar with forensic speech science;
2. To outline the transferability of innovative methodological developments in forensics and sociophonetics, and to highlight the impact of each field on the other; and
3. To suggest directions for future collaboration, in particular with regard to the development of new methods, sharing of large corpora and empirical data, and the collection of written descriptions of language varieties.

Although both authors are involved in sociophonetic research, we are primarily forensic speech scientists. Therefore, our focus on the benefits of collaboration from the perspective of forensics is based purely on greater experience with that discipline. However, we believe that there are many reciprocal benefits for both fields. We see collaboration as a positive endeavour, but recognise that there are issues and concerns associated with collaboration; in Section 4 we attempt to address these issues.

2 The (forensic) case for greater collaboration

2.1 Forensic voice analysis as applied sociophonetics

The analysis of the voice has long been admitted as a form of expert evidence – the dialectologist Stanley Ellis was one of the first experts in the UK to be involved in forensic casework, most (in)famously in the case of the Yorkshire ripper (Ellis 1994). The use of voice evidence has increased considerably more recently with between 500 and 600 cases per year in the UK now involving some form of voice evidence (French 2017). Voice evidence is also widely admitted in courts throughout Europe (including Spain, Germany and Sweden), North America, China, Australia and New Zealand. In many of these countries, analysis is

conducted by Government forensic labs. The most commonly sought analysis is forensic voice comparison (FVC), accounting for approximately 70% of all voice evidence cases (Foulkes and French 2012). FVC involves the analysis of a questioned recording containing the voice of an unknown speaker and comparing this to the voice of a known speaker. The issue is the identity of the unknown speaker, and it is the role of the expert, to analyse the known and questioned material and assess whether the voices belong to the same or different speakers. For the evidence to be useful to the court, the expert considers not only the similarity between the two voices, but also their typicality within the wider population; voices that contain rare features relative to the speech community will provide stronger evidential value than voices that are very 'typical' for the group. The court can then use this expert evidence in combination with other strands of evidence to arrive at their verdict.

Evidential voice recordings are unlike the recordings commonly collected and analysed in sociophonetic research. This is due to three main factors. Firstly, there are usually issues relating to the technical characteristics of the recordings. Many questioned recordings have been transmitted over the telephone. Telephone transmission affects the speech signal in a number of significant ways, primarily by reducing the bandpass frequency (between approx. 300Hz and 4000Hz); this artificially increases estimates of the frequency of F1 (Künzel 2001). Known recordings are usually of better quality, which thus leads to a mismatch in technical characteristics and reduces the comparability of the speech. Secondly, there are **speaker** factors which arise. There is always a time difference between the questioned and known recordings (i.e. they are *non-contemporaneous*). In addition, there may be differences in speech modalities (e.g. raised vs lowered voice, whisper, shouting), emotional level, and intoxication, amongst many other factors. There may also be variation between recordings due to differences in register, interlocutor and topic. Finally, there are **situational** factors such as overlapping speech and background noise particularly in questioned samples which reduce the amount of speech available for analysis.

In Europe, linguistic and phonetic methods have long been the predominant approach used in casework (see Gold and French 2011, Morrison et al 2016). This involves the *componential* analysis of variables at multiple linguistic levels (see French et al. 2010). The approach relies on long-established methods of auditory and acoustic analysis commonly used in sociophonetics, such as f0 and formant frequency measurements, IPA transcription, and voice quality profiling. The value of the evidence is assessed by considering how similar the

features are, and how unusual the linguistic patterns are relative to other speakers of the same variety. In this way, forensic analysis in casework can be viewed as applied sociophonetics.

2.2 The changing face of forensic (speech) science

Over the last few decades, there has also been increasing focus on the use of automatic methods (such as automatic speaker recognition systems; ASRs) for forensic voice analysis. These systems have been developed predominantly within the field of speech technology and use signal processing techniques to analyse the recordings. Automatic systems treat the speech as a signal; extracting and modelling data from all of the speech in a recording. As such, systems generally do not involve analysis of any discrete linguistic units, such as phonemes (although see Franco-Pedroso and González-Rodríguez 2016) and the measurements extracted are typically Mel frequency cepstral coefficients (MFCCs). ASR evidence has (to date) only been tendered in one case in the England and Wales courts (French 2017). In other countries (e.g. Germany, Sweden, Spain), ASR is used more regularly.

Forensic science as a whole is also changing. There has been a claimed *paradigm shift* (Saks and Koehler 2005) in the frameworks used to analyse, evaluate, interpret, and present expert evidence. There are two key elements to this. The first is validation; the ability of the expert to show that the methods used work. This requires testing performance using recordings which reflect casework conditions where the ground truth is known. The second element is data-driven assessments of typicality. While previously analysts across forensic science generally relied on their experience to estimate the typicality of certain features and the resultant strength of forensic evidence, the *paradigm shift* has led to demands for the use of more scientifically defensible and replicable methods based on empirical data.

2.3 Issues for forensic speech science

In a FVC analysis the expert has to assess the degree of similarity between a questioned and reference recording (e.g. do the speakers in both recordings have [v] for non-initial /ð/?) and also the typicality of those similarities (e.g. how many other speakers from this accent group might have [v] for /ð/?). For many variables in many varieties, there is no published literature available (e.g. what proportion of young men from Cardiff have a nasal voice quality?).

Ultimately, this leaves the assessment of typicality up to the expert themselves, which is somewhat problematic. Worryingly, as shown by Ross, French and Foulkes (2016), experts offer very different estimates on the rarity of linguistic features within different speech communities.

Robust validation and estimations of typicality require considerable amounts of data (both quantitative and qualitative). However, this is a significant challenge for forensic speech science, due to the lack of available corpora, databases of empirical reference data (e.g. collections of acoustic measurements) or up-to-date comprehensive descriptions of language varieties which can be used to evaluate voice evidence. Save a few notable exceptions devised with forensic purposes in mind (see section 3.2), sociophonetic corpora that do exist are limited in various ways. Sociophonetic corpora are extremely useful in that they generally control for important regional and social factors, however, the recordings are typically not 'forensically realistic' (see Section 2.1). An additional limitation is that they are usually relatively small in terms of the number of speakers required, especially for ASR systems (where, minimally, around 400 speakers are required just to train the system). The corpora used in ASR systems are often large, but not sufficiently well controlled in terms of the regional and social make-up of the speakers – most are only controlled for biological sex (male/female) and language.

A further consideration is the 'shelf life' of any form of data. For the purposes of most forensic casework, it is essential to have up-to-date data reflecting current patterns in the relevant community. Loakes (2006) found that vowel formant data from a corpus collected around 30 years before the evidential recordings, misrepresented the true strength of evidence, or, in the worst case, led to misidentifications. This is also relevant for descriptions of language varieties. In some cases, experts still rely on impressionistic data based on an analysis of one or two speakers and which is well over 30 years old (e.g. Wells 1982) for assessing typicality. The use of out-of-date reference data may have profound effects on the outcome of forensic analyses. For example, we may overstate the value of finding /h/-fulness in two recordings of Multicultural London English (MLE) if we rely on old descriptions of London English (which traditionally has /h/-dropping), rather than looking at more up-to-date studies which show /h/-fulness on the rise in MLE (Cheshire et al 2008).

3 Sharing methods and knowledge

Currently forensics relies on piecemeal data for testing and assessing typicality, either in the form of corpora, empirical data, or published literature, if indeed the data exist for the given variable and variety in a case. Thus, experts generally still rely on their experience in most cases. This needs to change if forensic speech science is to fall more closely in line with other forensic sciences. The solution is a continuous approach which includes greater collaboration and engagement with sociophoneticians.

3.1 The contribution of sociophonetics to forensics

In this section, we consider the ways in which sociophonetics is already contributing towards improving the validity, reliability, and replicability of forensic experts' conclusions, and how these practices could be expanded. Specifically, we explore (1) developments in elicitation and recording methods, (2) development and sharing of large scale corpora of recordings and empirical data, and (3) descriptions of language varieties. Our aim in this section is to highlight how research may be extremely useful to forensics in ways researchers may not have realised.

Elicitation and recording methods

As outlined in Section 2.1, forensic recordings are almost always non-contemporaneous, made in different contexts, under different emotional pressure, with different interlocutors. Traditionally, sociophonetic corpora contain a single good quality recording per speaker to facilitate auditory and acoustic analyses. Increasingly, however, researchers are recording multiple interactions from participants as the theoretical questions addressed shift the focus away from speakers at a static time point defined by macro-social categories. Ethnographic (Eckert 2000, Feagin 2013, Buchstaller and Khattab 2013), real-time (Sankoff 2004, Rhodes 2012), and within-speaker variability (Podesva 2007, Sharma 2011, Boyd et al 2015) studies contain speech which is well-suited to forensic research; value to forensics being a by-product of the primary aims of the research.

Additionally, forensic recordings are often sub-optimal in terms of quality. This has substantial effects on the speech signal, and the analysis which can be undertaken,

particularly on acoustic measurements. The availability of corpora containing sub-optimal quality recordings and/or multiple sessions per speaker is extremely valuable for forensic research and casework. Some sociophonetic studies have considered the effects of poor quality recordings on acoustic analysis methods (e.g. Rathcke et al 2016), and this research is incredibly valuable to practitioners who need to assess what methods are suitable given the recording characteristics.

Sociophonetic data collection is, of course, conducted according to the requirements of the study. In this section we have tried to identify areas of cross-over and highlight the ways in which material can have multiple uses by characterising the types of recordings common in forensic casework. We would encourage colleagues to consider these issues when designing large projects involving data collection and consider whether it may be possible to record some participants twice, or to make simultaneous telephone recordings of sessions. The resulting corpora would be of great benefit to both fields, not least because a single recording is only a snapshot of a speaker's repertoire.

Development and sharing of corpora and empirical data

Implicit within the previous section is the idea of sharing corpora and empirical data (e.g. spreadsheets of vowel formant data). For forensics, the availability of corpora and empirical data is essential to fulfil the demands of the paradigm shift.

Increasingly, linguists are endeavouring to provide access to recordings and/or analyses as a matter of course and sociophonetics is at the forefront of the big data revolution in linguistics. Resources such as the Atlas of North American English (Labov, Ash and Boberg 2006) and the British Library Sound Archive (http://sounds.bl.uk/) provide valuable access to recordings and, in some cases, analyses of different varieties. Software such as SLAAP (Kendall 2007, 2008), LaBB-CAT (Fromont and Hay 2012), and SPADE (Mielke, Sonderegger and Stuart-Smith 2017) allow for corpora to be stored, searched, and analysed and is increasingly accessible. This is invaluable for researchers interested in spoken language, and opens up opportunities for collaboration between sociophoneticians and forensic speech scientists.

As it becomes available, there are a number of ways in which empirical data can be used in the forensic context. For assessing typicality, data would be used to calculate population distributions for features in a given variety. These could then be used in casework to assess the typicality of a given feature observed in the known and questioned recording. For example, imagine a case in which the questioned and known speakers have a GOOSE vowel with an F2 around 1200Hz. The speakers in each recording are young adult men and speak with Greater Manchester area accents. Empirical data from Greater Manchester would enable the expert to assess whether this average F2 was typical for the variety, or whether these values are at the tails of the distribution. For this purpose, it would not be necessary to be able to listen to the recordings, having access to the empirical data would be sufficient (either generated automatically (although see Foulkes et al 2018) or available from previous studies). For the purposes of validation of methods, access to recordings may be more important, especially for testing automatic systems.

Descriptions of varieties

Up-to-date, comprehensive descriptions of varieties are often not produced nowadays in sociophonetics. This is partly due to theoretical developments in the field which focus on answering questions which require detailed analysis of a more limited range of variables across multiple speakers and speaking contexts. According to Foulkes and Docherty "the concentration on a selection of variants … usually results in large portions of the collected data being unpublished, or only partly analysed, and often even wholly untouched" (1999: 2-3). One of the core aims of their book, *Urban Voices* (Foulkes and Docherty 1999), was to present descriptive material for a range of British English varieties, formatted in the same way to allow comparison across varieties. Similarly, works like Wells (1982), Hughes, Trudgill and Watt (2012), and the Illustrations of the IPA are still widely used as baselines of accent descriptions.

Descriptions of language varieties are extremely valuable to those interested in variation and provide a useful benchmark from which to observe sound change or assess typicality. We believe that through continuing to develop ways in which we can share resources we can improve the quality of our reference descriptions. One way we propose that this may be done is through a wiki – a community-driven repository of information which could be a central resource containing descriptive information with a fixed format which is quick to use and

access (see Hughes and Wormald 2017). Rather than being a single resource, this wiki would signpost users to relevant academic articles, online resources (e.g. SPADE, SLAAP), or project websites, as well as providing useful summaries of accents and features.

3.2 The contribution of forensics to sociophonetics

It is clear that sociophonetic research has an incredibly beneficial impact on forensics. In this section we wanted to highlight ways in which forensic research and methods, as well as the suggestions made in Section 3.1, can contribute to sociophonetics.

The analysis of 'real-world' recordings in forensics offers unique possibilities to sociophonetics in terms of exploring and understanding the extent to which voices can vary (see for example Roberts (2012) which examined f0 variability in speakers under considerable physical and emotional stress). The focus in forensics on the individual also provides theoretical insight into the role of individual speakers in language change and the relationship between individual and group behaviour (see Hughes and Foulkes 2016). From a practical perspective, research in forensics (see Harrison 2013, Hughes et al 2018, Alzqhoul, Nair and Guillemin 2015) highlights the sensitivity of acoustic measurements to transmission type and the technical quality of recordings, as well as recording device and the software and settings used to perform the analysis; issues that sociophoneticians need to be, and increasingly are aware of (de Decker and Nycz 2011, Rathcke et al 2016 and see also Foulkes et al 2018).

As evidenced by the increase in data sharing in sociophonetics and linguistics more generally, the availability of large scale corpora allows researchers to answer previously untestable research questions, particularly related to predictability and functional load (see the recent special issue of *Linguistics Vanguard* on this topic). Large corpora collected recently for forensic purposes (e.g. DyViS – Nolan et al 2009; WYRED – Gold, Ross and Earnshaw 2018) are also publically available, and may, in the future, be added to sociophonetic platforms such as SPADE (Mielke, Sonderegger and Stuart-Smith 2017). The benefits of such platforms is for forensics are primarily of accessibility and efficiency. Having a range of corpora available on platforms that make large-scale acoustic analysis quick and easy will necessarily expand the extent to which forensic experts can use data when assessing typicality in casework. Indeed, we consider such platforms essential for this

purpose. The availability of forensic corpora on such platforms means that such recordings can also be used for sociophonetic research. Further, as highlighted by Foulkes and Docherty (1999), information sharing in the form of written descriptions of varieties is in itself extremely valuable to sociophonetics as it provides baseline data for assessing change over time. Such descriptions have value for other fields such as speech technology, and speech and language therapy (Foulkes, Scobbie and Watt 2010).

Novel methodological techniques from forensics, and particularly the automatic side of forensic analysis, are also increasingly being used to perform innovative research in sociophonetics (see Brown and Wormald 2017). But perhaps the greatest overlap between the fields in terms of methodologies can be seen in the attempts to integrate sociophonetic knowledge into ASR systems (as well as other applications of speech technology), in an attempt to improve their performance and better understand their underlying workings (Gonzalez-Rodriguez et al 2014, Hughes et al 2017).

4 Discussion

In this paper we have argued for greater collaboration between sociophonetics and forensic speech science. We have highlighted how ongoing methodological and theoretical developments in sociophonetics are helping to address challenges in forensics, and have presented suggestions for ways in which methods can be further expanded to, hopefully, benefit all. As a direct way forward, we believe it would be useful to target conferences and workshops for collaborative engagement. Specifically, we want to encourage introductory workshops and talks on forensic speech science at linguistics (including sociophonetics, sociolinguistics and phonetics) conferences such as NWAV (similar to the workshop in 2017), UKLVC and ICLaVE. Perhaps even more importantly, forensics would benefit from a much stronger linguistics presence at speech science and technology conferences, in particular Interspeech and the Odyssey Speaker and Language Recognition workshop.

We recognise that some colleagues may have concerns around collaboration with forensics. It appears there are two main issues; issue one is one of perception, and issue two is one of ethics. Considering perception first, the term ‘forensics’ brings with it certain baggage – associated with crime and punishment, and more worryingly discrimination and miscarriages of justice – especially in certain countries. We hope that in this paper we have clarified the

scope of how recordings and data could be used in forensic casework – as a means of assessing typicality or testing the overall performance of a method. For these purposes, no identifying information is required, indeed even access to recordings would not be required in most cases. Further, corpora would never be used to search for or identify potential suspects by law enforcement agencies. The intention of our proposals is to use collaboration to improve the quality of forensic voice evidence. We want to reassure colleagues that irrespective of which party is instructing, a good and reputable forensic expert's duty is to be an unbiased, objective witness for the court. Thus, while an expert's evidence may contribute to a court's decision to arrive at a guilty verdict, it could equally contribute to a court's decision to exonerate an individual. It is not the expert's job to comment on an individual's guilt or innocence, it is the expert's job to explain to the court the value of evidence when the court cannot be reasonably expected to understand themselves. In terms of ethics, when participants agree to be part of a study, they may not have consented to their data being used for forensic research or casework. This is likely to be more pertinent with existing corpora and data. As ever, issues of ethics must be taken seriously and the terms of the consent given by participants must be put first and respected over any research goals.

We want to conclude with direct messages to colleagues in both fields. Firstly, sociophonetic research is extremely valuable to forensics and can be even more valuable in the future through closer collaboration. We encourage colleagues to consider our suggestions within the constraints of their existing research and what is possible within future projects. We believe that there are also substantial benefits for sociophonetics by considering forensic issues, in particular due to the types of real-world recordings that are commonly analysed. Engagement with forensic issues can also provide research impact, which is a particularly important issue for all academics; impact involves showing how research is important beyond its academic value, in changing, benefiting, and influencing society and culture. Secondly, forensic speech scientists should engage more with sociophonetics to make sure they are aware of developments within the field, and to foster collaboration. Forensics needs to work harder to demonstrate and explain the benefits of sociophonetic research on forensic casework, and to share methods and results more widely. This involves thinking about the broader theoretical and practical implications of forensic work that may be beneficial to sociophonetics, beyond the specific task being undertaken in a given case.

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